DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGIC MAP AND DISTRIBUTION OF HEAVY MINERALS IN TERTIARY ROCKS OF THE RENO JUNCTION 30'×60' QUADRANGLE, CAMPBELL AND WESTON COUNTIES, WYOMING

By N. M. Denson, D. L. Macke, and R. R. Schumann

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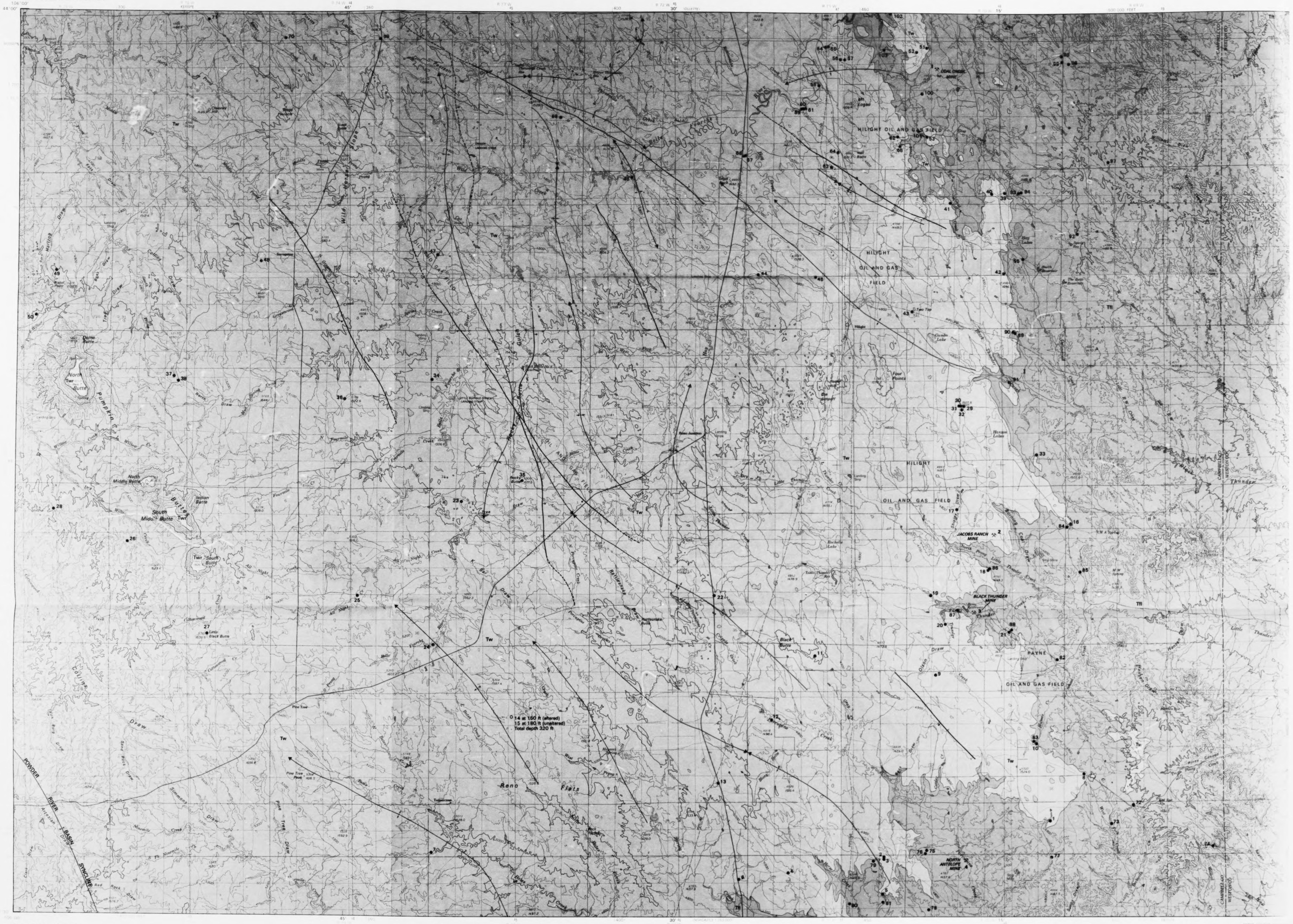

HILIGHT OIL AND GAS FIELD
HILIGHT OIL AND GAS FIELD
HILIGHT OIL AND GAS FIELD
JACOBS RANCH MINE
BLACK THUNDER MINE
PAYNE OIL AND GAS FIELD
NORTH ANTELOPE MINE
Reno Flats
POWDER RIVER BASIN SYNCLINE
North Butte
North Middle Butte
South Middle Butte
South Butte
Pumpkin
Tw
Ttl
14 at 150 ft (altered)
15 at 180 ft (unaltered)
Total depth 320 ft

Base from U.S. Geological Survey, 1974
Projection and 10 000-metre grid, zone 13: Universal Transverse Mercator. 1927 North American datum
50 000-foot grid ticks based on Wyoming coordinate system, east zone

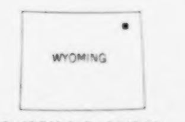
APPROXIMATE MEAN DECLINATION 1989

SCALE 1:100 000

1 ½ 0 1 2 3 4 5 MILES

1 .5 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929



QUADRANGLE LOCATION

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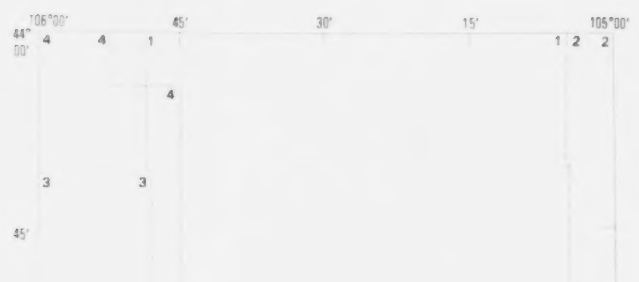
106°00'
45'
30'
15'
105°00'
44°00'
45'
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4
4
1
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4
3
3
4
4
3
3
5
5
5
5
1
1
2
2

INDEX SHOWING SOURCES OF GEOLOGIC DATA

[Numbers indicate areas of previous mapping from which the present geology is modified]

1. Denson, N.M., Dover, J.R., and Osmonson, L.M., 1980, Lower Tertiary coal bed distribution and coal resources of the Reno Junction-Antelope Creek area, Campbell, Converse, Niobrara, and Weston Counties, Wyoming: U.S. Geological Survey Miscellaneous Investigations Series Map I-1201, scale 1:125,000.
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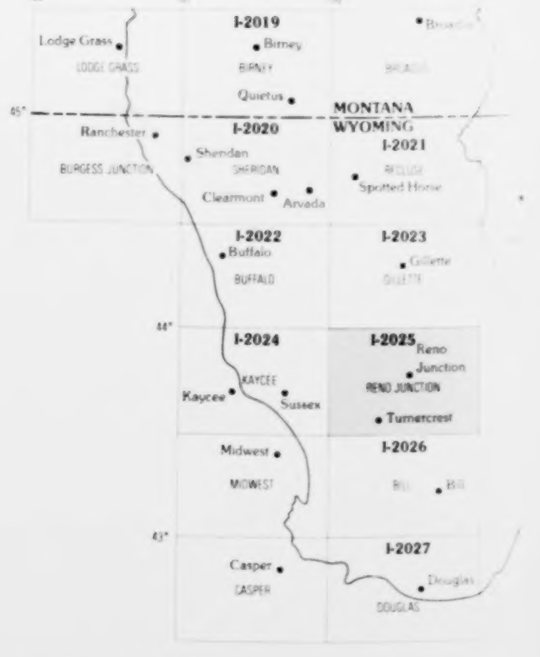
By

N. M. Denson, D. L. Macke, and R. R. Schumann

1989


I-2019
Lodge Grass
LODGE GRASS
Birney
BIRNEY
Quietus
MONTANA
WYOMING
I-2020
Ranchester
BURGESS JUNCTION
Sheridan
SHERIDAN
Clearmont
Arvada
I-2021
Spotted Horse
I-2022
Buffalo
BUFFALO
I-2023
Gillette
GILLETTE
I-2024
Kaycee
KAYCEE
Sussex
I-2025
Reno Junction
RENO JUNCTION
Turnercrest
Midwest
MIDWEST
I-2026
I-2027
Casper
CASPER
Douglas
DOUGLAS

INDEX MAP SHOWING LOCATION OF THE RENO JU
SURROUNDING 30′ × 60′ QUADRANGLES AND THE AP
OUTLINE OF THE POWDER RIVER BASIN AS DRA
BASE OF THE LANCE FORMATION. YELLOW SHADIN
COMPANION I-MAPS

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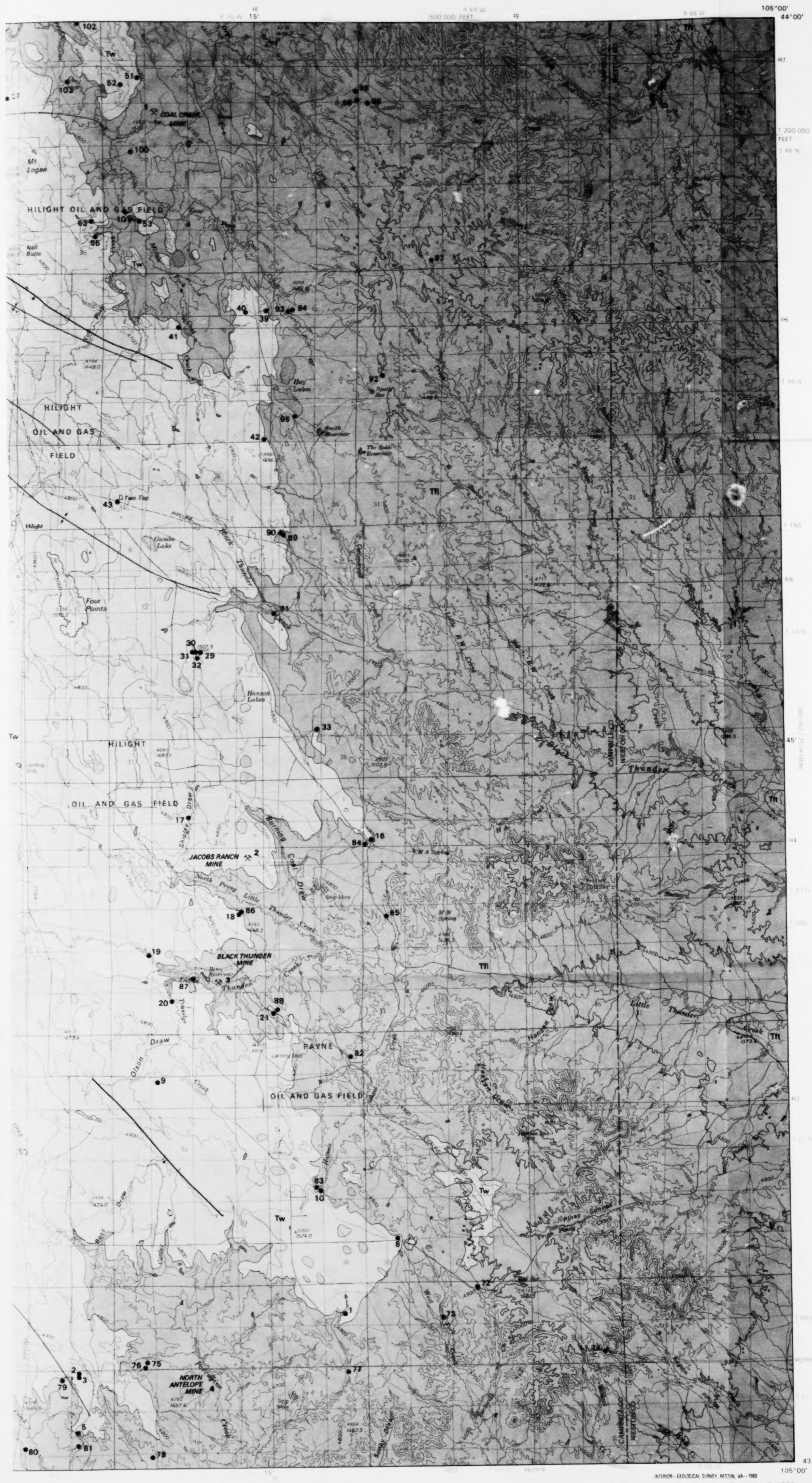

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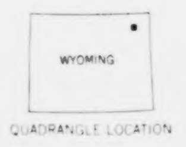


CORRELATION OF MAP UNITS

- Twr — Oligocene
- Unconformity
- Tw — Eocene
- Unconformity
- Tfl, Tft — Paleocene
- TERTIARY

DESCRIPTION OF MAP UNITS

Twr **White River Formation (Oligocene)**—Gray, massive, coarse-grained sandstone overlain by very coarse, hard, locally conglomeratic sandstone; forms caprock on Pumpkin Buttes. Near center of south half of sec. 32, T. 44 N., R. 75 W., caprock is locally overlain by less than 10 ft of blocky, white and pink tuff and bentonitic claystone, which has yielded vertebrate fossils of early Oligocene age. Unconformably overlies Eocene Wasatch Formation. Thickness 130–250 ft

Tw **Wasatch Formation (Eocene)**—Reddish-brown, tan, and gray, medium- to coarse-grained sandstone, siltstone, carbonaceous shale, claystone, and coal; all of fluvial and paludal origin. Contains many lenses or pods of hematitic- and limonitic-cemented material, which locally imparts a red color to the unit. In general, sandstone is coarser grained and contains two to three times more heavy minerals than sandstone of underlying Tertiary rocks. Tschudy (1976) considers that the lower 500 ft in the vicinity of Gillette, Wyoming, is Paleocene in age, on the basis of palynological evidence. Vertebrate fossils, found in the southwestern part of the Powder River Basin, have been assigned an early Eocene age by Delson (1971). Typical Paleocene pollen have not been found at most of the vertebrate localities. The authors conclude that the age of the Wasatch Formation in the Reno Junction 30′ × 60′ quadrangle may only be Eocene, as shown on the geologic map of Wyoming (Love and Christiansen, 1985). Unconformably overlies Fort Union Formation and is truncated by present-day erosion surface. Thickness 0–2,250 ft

Fort Union Formation (Paleocene)

Tfl **Lebo Member**—Light- to dark-gray, very fine grained sandstone interbedded with varying amounts of siltstone, claystone, carbonaceous shale, and coal; all of fluvial and paludal origin. Brown-weathering, calcareous, iron-rich, cauliflower-shaped concretions, ranging from less than an inch to several feet in diameter, are interbedded throughout unit with massive, white sandstone and light- to dark-gray, slightly bentonitic shale. Locally, coal beds are more than 150 ft thick. In general, sandstone included in the Lebo Member is finer grained and better sorted than that in the Wasatch Formation. Also, the percentage of heavy minerals in the Lebo Member sandstone is generally less than 0.2 percent. Thickness 1,370–3,280 ft

Tft **Tullock Member**—Interbedded sandstone, siltstone, shale, carbonaceous shale, and thin coal beds. The drab appearance and massive sandstone beds of the Tullock Member easily distinguish it from the conformably overlying Lebo Member, which generally has a lighter overall color and a predominance of siltstone and shale. Exposed only along east margin of quadrangle. Thickness 780–1,700 ft

Contact

High-angle fault—Dashed where inferred; ball and bar on downthrown side

Anticline—Showing axial trace and direction of plunge

Syncline—Showing axial trace and direction of plunge

○ **Drill hole**—Showing sample numbers, depth at which samples were taken, and total depth

● **Sample locality**—Samples of Tertiary rocks collected for heavy-mineral analyses. Numbers are referred to in table 1

⚒ **Coal strip mine**—Locations as of January, 1988, supplied by the Office of Surface Mining Reclamation and Enforcement, Western Field Operations, Denver, Colorado. Numbers are referred to in table 3

Note: Structural features shown on map are mostly based on structure contours drawn on base of Wyodak or Anderson coal bed (see Denson and others, 1980)

INTRODUCTION

Reports prepared during the early part of the 20th century, such as Taff (1909), Wagemann (1918), and Baker (1929), describe the Fort Union-Wasatch contact in the Powder River Basin, but indicate few criteria for placement of the contact at most places. Since then it has been variously placed, generally at a marker bed such as a coal bed or a coquina bed, which is 200–300 ft above the mineralogic and lithologic changes that actually mark the boundary between the formations. In rocks having low dip values (1°–2°), which include the surface rocks across most of the Powder River Basin, this variance of 200–300 ft in the placement of the contact may result in a difference of several miles in placing the contact on a geologic map. The results of this study show that changes in heavy-mineral suites are distinct enough to be of use in stratigraphic correlation and in placement of the Fort Union-Wasatch contact. In most areas sampled, rocks assigned to the Paleocene Fort Union Formation contain heavy-mineral suites derived mostly from the weathering of pre-existing Paleozoic and Mesozoic sedimentary rocks, with relatively minor local contributions from Precambrian rocks (Denson and Pipiringos, 1969). Uplift and erosion of the Precambrian rocks in the mountains adjacent to the Powder River Basin in early Eocene time is clearly shown by the abrupt appearance of blue-green hornblende in the Wasatch Formation (Denson and Chisholm, 1971).

In addition to differences in the heavy-mineral suites, the following criteria were used in selecting the contact between the Fort Union and Wasatch Formations in this and the adjacent Bill quadrangle. (1) In general, sandstone of the Wasatch Formation is coarser grained and has more grain-size variation than sandstone in the Fort Union Formation. Characteristically, the Wasatch Formation weathers from very light gray to tan, whereas the Fort Union Formation weathers from very light gray ("glistening white") to somber shades of gray. (2) Ganister (orthoquartzite) boulders and blocks containing numerous root and leaf impressions occur at the top of the Fort Union Formation at many places, and they are commonly found near the Fort Union-Wasatch contact. (3) Brown-weathering, calcareous, iron-rich, cauliflower-shaped concretions, which range from less than 1 inch to several feet in diameter, are common in the Fort Union but are generally absent in the Wasatch Formation. (4) Hard, dense, limonitic- and hematitic-cemented sandstone beds ranging from 1 to 3 ft thick, are present at many places in the Wasatch Formation at or near the contact with the Fort Union Formation.

The placement of the contact between the Fort Union and Wasatch Formations has direct implications for uranium exploration within the basin. An example from the adjacent Bill 30′ × 60′ quadrangle is the inclusion of the host rocks of the Exxon uranium mine (sec. 28, T. 36 N., R. 72 W.) in the Fort Union Formation by Dahl and Hagmaier (1976). Here, as at other places in the southern part of the Powder River Basin, the contact was placed at the top of the Badger coal bed (Sharp and Gibbons, 1964, pl. 1) approximately 480 ft above the change in heavy-mineral assemblages and therefore within the Wasatch Formation rather than at the Fort Union and Wasatch contact. The location of the Badger coal mine from which the Badger coal bed was informally named is in the SE1/4 SW1/4 sec. 15, T. 36 N., R. 75 W., Converse County, Wyoming. To the authors' knowledge, except for some mineralized areas in the Fort Union Formation north and east of Kaycee, Wyoming (Childers, 1970), most of the significant uranium deposits in the area occur in the lower part of the Wasatch Formation.

We interpret the Fort Union-Wasatch contact in the Reno Junction quadrangle to be an unconformity on the basis of differences in lithology as discussed above and by truncation of coal beds in many places in the Fort Union Formation below the unconformity (Denson and others, 1980). The significance and understanding of this unconformity is critical to the commercial development and reclamation of the strippable coal reserves in the eastern part of the Powder River Basin.

The Tertiary rocks in the Reno Junction quadrangle are continental in origin and range in thickness from 1,000 to 7,500 ft. They include the lower Eocene Wasatch Formation and the Paleocene Fort Union Formation. Additionally, erosional remnants of the lower Oligocene White River Formation, 150–250 ft thick, cap the Pumpkin Buttes in the west-central part of the quadrangle. One hundred and three samples were collected from these rocks for mineralogic study (table 1). Stow (1938) used data on the relative abundances of nonopaque heavy-mineral grains in Tertiary rocks in the intermontane basins of Wyoming and Montana to define formations and locate contacts. The same procedure was followed in our study to define and locate the contact between the Wasatch and Fort Union Formations.

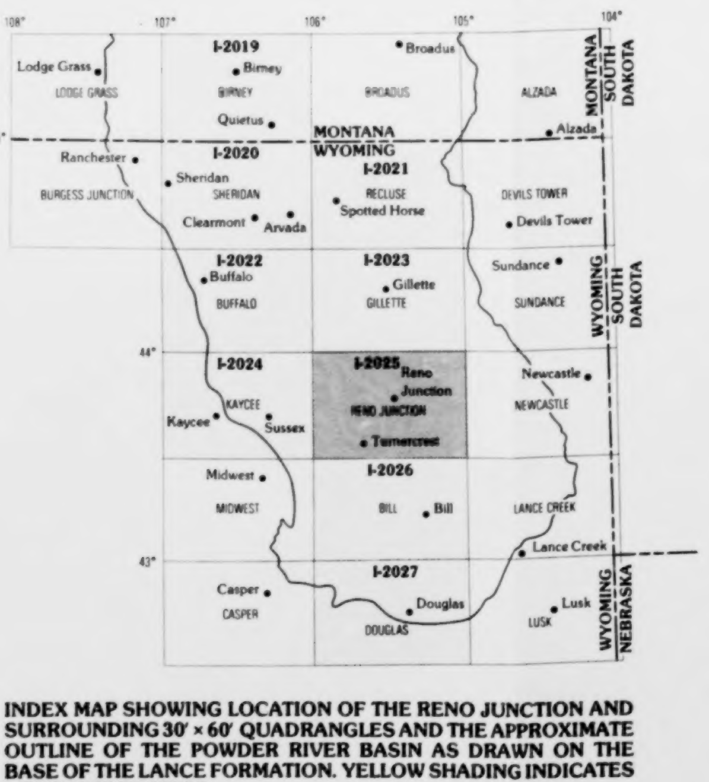
The maximum combined thickness of all strata in the Reno Junction quadrangle is about 18,000 ft. Maximum topographic relief in the quadrangle is 1,640 ft; the highest elevation is 6,052 ft on the crest of North Butte, in the west-central part of the area. The lowest elevation is about 4,612 ft where Pumpkin Creek leaves the northwest corner of the quadrangle.

The northeastward flowing Belle Fourche River and its tributaries drain most of the north-central part of the quadrangle, whereas the northwestward flowing tributaries of the Powder River drain most of the western part of the area. Pumpkin Buttes, which rise 500–600 ft above the surrounding area, are capped by strata of the Oligocene White River Formation. These northwest-trending buttes form a prominent drainage divide that extends about 10 mi along the west-central margin of the quadrangle. Most of the southern and eastern parts of the quadrangle are drained by tributaries of Antelope Creek and the Cheyenne River, which are south and east of the quadrangle. Ninemile, Bates, Spring, and Porcupine Creeks drain most of the southern parts of the area, and the southeast-flowing Little Thunder, Black Thunder, and Buck Creeks drain most of the eastern parts of the quadrangle.

The terrain in the eastern part of the quadrangle, generally less than 4,900 ft elevation, is flat to gently rolling except along the eastern margin of the quadrangle where locally it has been eroded into prominent, irregular breaks in topography, commonly referred to as badlands. Flat-topped buttes and pinnacle-like hills capped by clinker (which resulted from the burning of coal beds in the upper part of the Fort Union and lower part of the Wasatch Formations) are common topographic features. The terrain extending across the western part of the area, in contrast to that of the eastern part, is mostly devoid of badlands and consists of large expanses of flatlands and gently rolling topography generally less than 5,500 ft in elevation.

ACKNOWLEDGMENTS

Mineral identifications were made by Wayne A. Chisholm. Samples were prepared by Robert F. Gantnier and Thomas D. Hessin. Samples were collected by the senior author, except 27 samples were collected in the Reno Junction area by Stanley P. Buck.



INDEX MAP SHOWING LOCATION OF THE RENO JUNCTION AND SURROUNDING 30′ × 60′ QUADRANGLES AND THE APPROXIMATE OUTLINE OF THE POWDER RIVER BASIN AS DRAWN ON THE BASE OF THE LANCE FORMATION. YELLOW SHADING INDICATES COMPANION I-MAPS

OF THE RENO JUNCTION
YOMING

REGIONAL GEOLOGY

The Reno Junction quadrangle is in the south-central part of the Powder River Basin in Campbell and Weston Counties, Wyoming. The Powder River Basin is a broad regional downfold that dominates much of the Northern Great Plains in southeastern Montana and in northeastern Wyoming west of the Black Hills. The basin is approximately 250 mi long and 90 mi wide. It is an elongated, markedly asymmetrical feature having a gently dipping east limb (1°–2°) and a relatively steeply dipping west limb (5°–6°). The deepest part of the basin is near its western margin (VerPloeg and others, 1980; Pierce and others, 1952). The index map shows the approximate outline of the Powder River Basin, which is drawn on the base of the outcrop of the Upper Cretaceous Lance Formation.

In the structurally deepest part of the basin, the combined total thickness of all strata is about 23,000 ft. Lower Tertiary (Paleocene and Eocene) strata crop out over most of the basin. These strata were once covered by several thousand feet of younger Tertiary rocks, most of which have been removed by erosion.

In this report, the Wasatch has been split into an upper part and a lower part to indicate that most mappers of Tertiary rocks in the Powder River Basin have been misled by the concept that the top of the Roland coal bed of Baker (1929, pls. 28 and 29) marks the contact beteen the Fort Union and Wasatch Formations. In order to show that the rocks overlying Baker's Roland coal bed are lithologically and mineralogically similar to the rocks underlying the Roland coal bed, samples collected above the coal bed are referred to in this report as the upper part of the Wasatch. Conversely, Wasatch samples collected below the top of Baker's Roland coal bed or its stratigraphic equivalent are referred to as the lower part of the Wasatch.

SAMPLE PREPARATION

The samples were disaggregated either by gentle crushing with a mortar and pestle or by dissolution of carbonate cement using dilute hydrochloric acid. Samples were sieved, and the heavy minerals were concentrated in bromoform. The heavy minerals were recovered from the very fine sand size fraction (0.062–0.125 mm) of most of the samples. A few samples, however, yielded too few grains of this size for adequate evaluation, so the coarse silt-size fraction (0.031–0.062 mm) was used. A few samples contained minerals coated with iron oxide or clay. Prior to mounting, the coated grains were cleaned in an ultrasonic cleaner in a bath of warm, dilute hydrochloric or nitric acid. Mineral abundances were determined by counts of 100 or more grains in samples mounted in Arochlor (index of refraction 1.66) or Canada balsam (index of refraction 1.54).

The magnetic opaque minerals, as much as 33 percent of the total heavy-mineral concentrate in some samples, were removed with an electromagnet before the nonopaque minerals were studied. These minerals, which include magnetite, ilmenite, ferruginous and clay aggregates, leucoxene, and pyrite, were not studied in detail.

RESULTS

Tables 1 and 2 and figure 1 show the results of this study. Dominant nonopaque heavy minerals from the Wasatch Formation are blue-green hornblende, epidote, or garnet, or a combination of these minerals. In contrast, the dominant heavy minerals from the Lebo Member of the Fort Union Formation are tourmaline, the pinkish-violet variety of zircon, and garnet (in order of decreasing abundance). These differences distinguish the two formations.

In addition to the heavy-mineral assemblages, minor accessory minerals also exhibit varying distributions in the Wasatch and Fort Union Formations. Apatite, biotite, and sphene generally characterize the minor accessory mineral suite in the Wasatch Formation, whereas rutile, staurolite, chloritoid, and an abundance of magnetic minerals tend to characterize the underlying Lebo Member of the Fort Union Formation. The diagnostic accessory mineral assemblage at any one locality can consist of one mineral but most mineral assemblages consist of more than one mineral.

The significance of the difference between the means (table 2) was tested at 90, 95, and 99 percent confidence levels using a two-tailed t test (Natrella, 1966).

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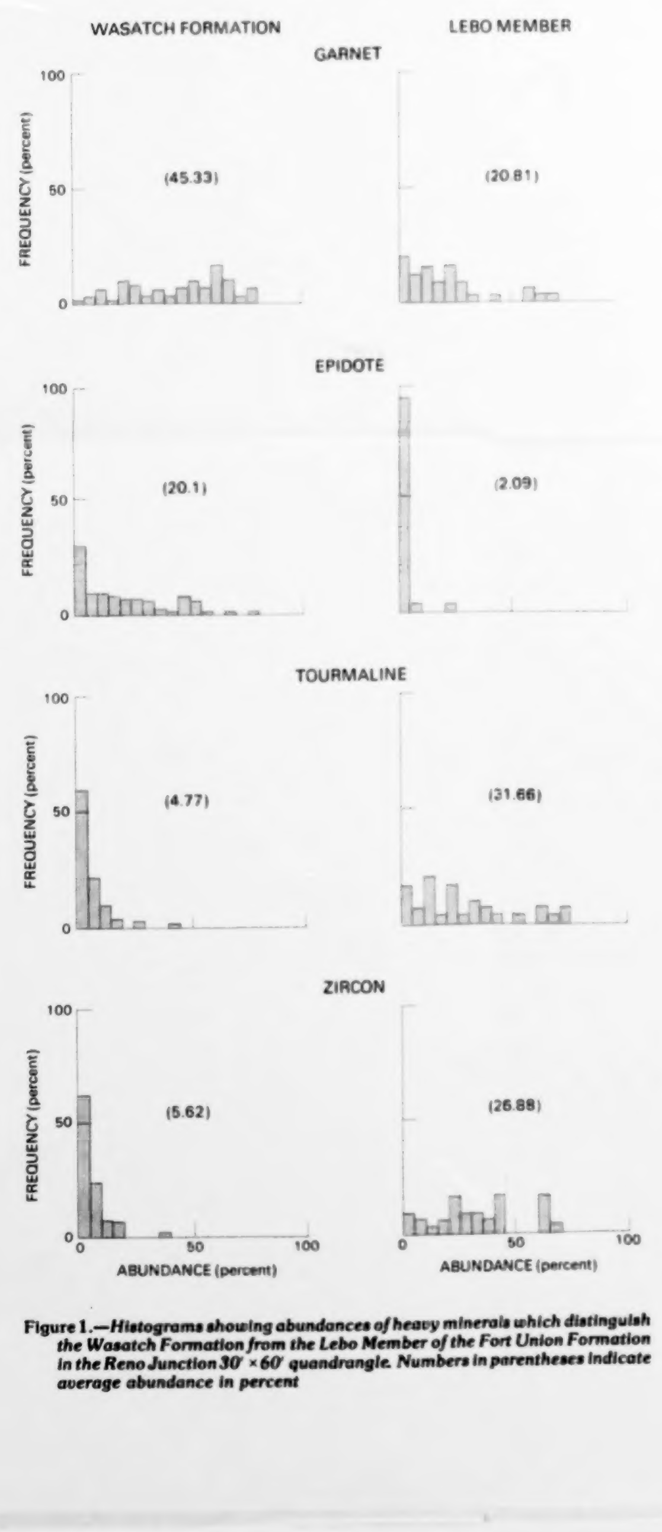

Figure 1.—*Histograms showing abundances of heavy minerals which distinguish the Wasatch Formation from the Lebo Member of the Fort Union Formation in the Reno Junction 30′ × 60′ quadrangle. Numbers in parentheses indicate average abundance in percent*

Table 1.—*Heavy-mineral analyses of samples from the Eocene Wasatch Formation and the Paleocene Fort Union Formation in the Reno Junction 30′ × 60′ quadrangle.*

[Asterisk (*) indicates sample collected from the upper part of the Wasatch Formation; leaders (-----) indicate data not available. Mineral identifications by W. A. Chisholm]

Sample number		Location								Heavy minerals, in percent (Total nonopaque minerals = 100 percent)																								
										Pyroxene		Hornblende																						
Map	Field	¼	¼	Sec.	T.	R.	Elevation (feet)	Percent of heavy minerals in very fine sand fraction	Percent of magnetic opaque minerals in total heavy minerals	Augite	Hypersthene	Gray	Green-brown	Blue-green	Garnet	Epidote	Zircon	Sphene	Rutile	Zoisite	Tourmaline	Sillimanite	Kyanite	Staurolite	Andalusite	Monazite	Allanite	Diopside	Apatite	Biotite	Anatase	Chloritoid	Chlorite	Spinel
Eocene Wasatch Formation																																		
1	DW2-14	NE	SW	1	41N	70W	4900	-----	-----	0	0	0	0	0	32	54	0	13	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
2	DW0-47	NW	NW	13	41N	71W	4880	0.21	0.77	0	0	0	0	0	25	42	2	11	0	0	6	0	0	0	0	0	0	0	0	14	0	0	0	0
3	DW0-48	NW	NW	13	41N	71W	4840	2.19	2.26	0	0	0	0	0	49	32	4	12	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	DW2-227	NW	SE	17	41N	71W	4945	-----	-----	0	0	0	0	3	54	31	1	8	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0
5	DW2-18	NW	SW	24	41N	71W	4820	-----	-----	0	0	0	0	0	62	10	6	14	1	0	3	0	0	0	0	0	0	0	0	3	0	1	0	0
6	DW5-70	SW	SE	13	41N	72W	4760	-----	-----	0	0	0	1	0	9	61	17	1	0	2	5	0	0	1	0	0	0	0	1	2	0	0	0	0
7	DW4-10	SW	SW	7	41N	73W	5040*	-----	-----	0	0	0	3	30	34	28	2	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	DW2-12	SW	SE	30	42N	69W	4980	-----	-----	0	0	0	0	0	54	0	11	12	3	0	7	0	0	0	0	0	0	0	5	8	0	0	0	0
9	DW2-1	NW	NW	8	42N	70W	4820	-----	-----	0	0	0	0	5	54	14	6	14	0	0	5	0	0	2	0	0	0	0	0	0	0	0	0	0
10	DW2-9	NE	SE	23	42N	70W	4860	-----	-----	0	0	0	0	0	36	15	7	15	2	0	3	0	0	1	0	0	0	0	0	21	0	0	0	0
11	DW4-16	SW	NE	4	42N	71W	5030	-----	-----	0	0	0	0	0	36	16	6	38	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
12	DW5-78	SE	SE	18	42N	71W	4790	-----	-----	0	0	0	0	1	23	6	40	1	3	0	16	0	3	5	0	0	0	0	0	0	0	1	0	1
13	DW2-226	SE	NE	35	42N	72W	5095*	-----	-----	0	0	0	1	13	24	54	1	4	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0
14	DW5-63	NW	SW	15	42N	73W	5020*	-----	-----	0	0	0	0	1	26	52	3	2	0	0	0	0	1	2	0	0	0	0	0	12	0	1	0	0
15	DW5-64	NW	SW	15	42N	73W	4980*	-----	-----	0	0	0	1	40	3	47	2	1	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0
16	DW2-7	NW	SW	7	43N	69W	4935	-----	-----	0	0	0	0	0	63	0	7	11	1	0	8	0	0	1	0	0	0	0	3	6	0	0	0	0
17	DW0-51	SE	SE	5	43N	70W	4750	0.10	4.04	0	0	0	0	0	24	1	15	47	3	0	5	0	0	0	0	0	0	0	1	2	0	2	0	0
18	DW2-4	NW	NW	22	43N	70W	4755	-----	-----	0	0	0	0	0	62	0	15	16	0	0	3	0	0	0	0	0	0	0	0	3	0	1	0	0
19	DW2-11	NE	NE	30	43N	70W	4710	-----	-----	0	0	0	0	0	22	46	6	5	1	0	8	0	1	1	0	0	0	0	0	8	0	2	0	0
20	DW2-2	NE	NW	32	43N	70W	4720	-----	-----	0	0	0	0	0	46	27	12	11	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
21	DW0-36	NE	SE	34	43N	70W	4800	4.03	3.34	0	0	0	0	0	68	2	14	6	2	0	2	0	0	0	0	0	0	0	4	0	0	0	2	0
22	DW2-225	NW	NE	26	43N	72W	5050*	-----	-----	0	0	0	0	0	76	0	3	0	2	0	10	0	0	0	0	0	0	0	0	7	0	2	0	0
23	DW5-76	SW	NW	5	43N	73W	4960*	-----	-----	0	0	0	1	7	59	14	4	9	0	0	0	4	0	0	0	0	0	0	0	1	1	0	0	0
24	DW5-75	SW	SW	31	43N	73W	5120*	-----	-----	0	0	0	0	0	47	24	8	9	1	2	3	0	0	0	0	0	0	0	6	0	0	0	0	0
25	DW4-1	NE	NW	27	43N	74W	5150*	-----	-----	0	0	0	1	6	60	19	3	9	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
26	DW9-62	NW	NE	18	43N	75W	5310*	0.35	0.29	0	0	0	0	0	77	20	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
27	DW9-61	NW	SE	34	43N	75W	5280*	0.69	16.75	0	0	0	1	19	20	48	0	7	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0
28	DW80-11	SE	SE	3	43N	76W	5085*	2.07	0.65	0	0	0	0	0	68	16	4	4	1	0	1	0	0	0	0	0	0	0	6	0	0	0	0	0
29	DW0-34	SW	SW	16	44N	70W	4932	-----	-----	0	0	0	0	0	52	8	12	4	12	0	8	0	0	0	0	0	0	0	0	4	0	0	0	0
30	DW2-214	SW	SW	16	44N	70W	4940	-----	-----	14	7	0	8	0	43	0	14	7	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0
31	DW0-44	SE	SE	17	44N	70W	4910	0.15	0.00	0	0	0	0	0	62	2	0	31	1	0	1	0	0	0	0	0	0	0	0	3	0	0	0	0
32	DW0-45	NW	NW	21	44N	70W	4915	0.12	1.58	0	0	0	0	0	78	3	3	10	0	0	3	0	0	1	0	0	0	0	1	1	0	0	0	0
33	DW0-46	SE	SE	26	44N	70W	4840	-----	-----	0	0	0	0	0	64	0	27	5	2	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
34	DW4-9	SW	SW	7	44N	73W	4940*	-----	-----	0	0	0	1	15	27	47	3	3	1	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0
35	DW5-74	NE	SW	34	44N	73W	5290*	-----	-----	0	0	0	0	0	55	26	2	11	0	0	1	0	0	1	0	0	0	0	3	1	0	0	0	0
36	DW5-77	NW	SE	16	44N	74W	5100*	-----	-----	0	0	0	6	43	17	20	1	7	0	0	1	0	0	0	0	0	0	0	3	2	0	0	0	0
37	DW80-10	SE	SW	9	44N	75W	5380*	0.16	0.00	0	0	0	0	0	69	17	0	8	0	0	2	0	0	0	0	0	0	0	1	3	0	0	0	0
38	DW4-2	NE	NW	16	44N	75W	5380*	-----	-----	0	0	0	0	1	41	50	2	3	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0
39	DW2-206	SE	SE	3	45N	70W	4680	-----	-----	0	0	0	0	0	63	0	2	11	1	0	16	0	0	3	0	0	0	0	0	0	0	4	0	0
40	HM4-3	SE	SW	3	45N	70W	4890	-----	-----	0	0	1	0	0	53	2	10	11	4	0	16	0	0	1	0	0	0	0	2	0	0	0	0	0
41	HM4-1	NE	NE	8	45N	70W	4710	-----	-----	0	0	0	0	0	69	0	3	12	2	0	6	0	0	2	0	0	0	0	5	1	0	0	0	0
42	DW2-205	SE	SE	22	45N	70W	4880	-----	-----	0	0	0	0	0	60	20	2	0	3	0	11	0	0	0	0	0	0	0	0	1	0	3	0	0
43	DW2-210	SE	NW	31	45N	70W	5025*	-----	-----	0	0	0	0	0	10	45	8	16	1	0	6	0	1	4	0	0	0	0	3	5	0	0	0	1
44	DW2-224	SE	SW	19	45N	71W	4820*	-----	-----	0	0	0	0	0	11	80	4	3	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
45	DW2-223	NW	NE	28	45N	71W	4940*	-----	-----	0	0	0	0	0	36	12	27	0	5	0	16	0	0	3	0	0	0	0	0	1	0	0	0	0
46	DW5-79	NE	NE	5	45N	72W	4700*	-----	-----	0	0	0	0	1	13	73	5	4	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0
47	DW4-4	NE	NW	19	45N	73W	4980*	-----	-----	0	0	0	0	0	52	35	0	5	1	0	0	0	1	0	0	0	0	0	4	2	0	0	0	0
48	DW4-3	SW	NE	24	45N	75W	5120*	-----	-----	0	0	0	18	34	28	11	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	DW4-28	NE	SE	22	45N	76W	5030*	-----	-----	0	0	0	6	74	11	8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
50	DW9-64	SW	NW	34	45N	76W	5040*	0.91	4.83	0	0	0	3	36	21	33	0	1	0	0	1	0	0	2	0	0	0	0	1	2	0	0	0	0
51	DW5-72	SE	NE	7	46N	70W	4700	-----	-----	0	0	0	1	0	65	1	1	15	0	0	7	0	0	0	0	0	0	0	9	0	0	1	0	0
52	HM4-9	NW	SW	7	46N	70W	4750	-----	-----	0	0	0	0	0	25	0	12	31	11	0	12	0	1	5	0	0	0	0	0	0	0	3	0	0
53	HM4-22	NW	SE	30	46N	70W	4650	-----	-----	0	0	0	0	0	68	0	2	9	0	0	7	0	0	0	0	0	0	0	3	11	0	0	0	0
54	HM4-17	SE	NE	9	46N	71W	4500	-----	-----	0	0	0	0	0	69	5	5	12	3	0	4	0	0	2	0	0	0	0	0	0	0	0	0	0
55	HM4-18	SW	NW	10	46N	71W	4560	-----	-----	0	0	5	0	0	72	6	1	6	0	1	4	0	0	0	0	0	0	0	0	3	0	2	0	0
56	HM4-19	SW	SE	10	46N	71W	4680	-----	-----	0	0	0	0	0	64	16	0	8	0	0	8	0	0	4	0	0	0	0	0	0	0	0	0	0
57	HM4-20	SW	SE	10	46N	71W	4670	-----	-----	0	0	0	0	0	73	0	0	16	1	0	4	0	1	0	0	0	0	0	4	0	0	1	0	0
58	HM4-16	SW	SE	16	46N	71W	4570	-----	-----	0	0	0	0	0	55	1	1	17	0	0	5	0	0	1	0	0	0	0	8	11	0	1	0	0
59	HM4-12	NW	SW	21	46N	71W	4560	-----	-----	0	0	0	0	0	64	9	4	10	2	0	3	0	0	0	0	0	0	0	2	6	0	0	0	0
60	HM4-13	NW	SW	21	46N	71W	4570	-----	-----	0	0	0	0	0	61	11	1	19	0	0	5	0	0	2	0	0	0	0	0	1	0	0	0	0
61	HM4-14	NW	SW	21	46N	71W	4580	-----	-----	0	0	0	0	0	29	36	7	10	5	1	7	0	2	1	0	0	0	0	1	0	0	1	0	0
62	DW0-39	NW	SE	25	46N	71W	4670	0.19	2.40	0	1	0	1	0	55	1	8	12	3	0	8	0	0	1	0	0	0	0	6	4	0	0	0	0
63	DW4-5	SW	SW	34	46N	71W	4980*	-----	-----	0	0	0	0	0	11	12	9	0	7	0	37	0	2	9	0	0	0	0	1	7	0	5	0	0
64	HM4-25	SE	NW	34	46N	71W	4750	-----	-----	0	0	0	0	0	21	0	7	38	1	0	13	0	0	0	0	0	0	0	4	12	0	4	0	0
65	HM4-23	NE	NE	36	46N	71W	4670	-----	-----	0	0	0	0	0	78	3	8	8	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
66	HM4-26	SE	NE	26	46N	72W	4640	-----	-----	0	0	0	0	0	63	6	1	18	0	0	10	0	0	0	0	0	0	0	0	2	0	0	0	0
67	HM4-27	SE	NE	36	46N	72W	4680	-----	-----	0	0	0	0	0	57	20	2	14	2	0	2	0	2	0	0	0	0	0	1	0	0	0	0	0
68	DW4-8	SW	SW	24	46N	73W	4965*	-----	-----	0	0	0	0	0	50	34	2	5	1	0	1	0	1	0	0	0	0	0	3	3	0	0	0	0
69	DW4-27	SW	SW	2	46N	74W	5198*	-----	-----	0	0	0	0	1	36	45	0	10	0	0	3	0	0	0	0	0	0	0	3	2	0	0	0	0
70	DW80-6	SW	SE	6	46N	74W	4971*	1.12	0.00	0	0	0	0	0	49	31	1	9	0	2	3	0	0	0	0	0	0	0	5	0	0	0	0	0
71	DW9-47	NW	NE	3	46N	75W	4925*	1.37	1.82	0	0	0	2	62	6	29	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paleocene Lebo Member, Fort Union Formation																																		
72	DW9-53	NW	NE	4	41N	69W	4900	0.03	20.00	0	0	0	0	3	4	0	60	1	4	0	20	0	3	3	0	0	0	0	0	2	0	0	0	0
73	DW4-17	SE	SE	5	41N	69W	4820	-----	-----	0	0	0	0	0	12	0	32	6	12	0	32	0	0	4	0	0	0	0	0	2	0	0	0	0
74	DW4-18	NW	SE	12	41N	69W	5040	-----	-----	0	0	0	0	0	24	4	20	12	2	0	28	0	2	8	0	0	0	0	0	0	0	0	0	0
75	DW0-93	SE	SE	7	41N	70W	4750	0.35	0.00	0	0	0	0	0	14	2	5	2	3	0	63	0	1	10	0	0	0	0	0	0	0	0	0	0
76	DW0-94	SE	SE	7	41N	70W	4790	0.27	0.00	0	0	0	0	0	55	0	4	26	1	0	7	0	0	1	0	0	0	0	0	4	0	0	0	0
77	DW2-13	NW	NE	13	41N	70W	4760	-----	-----	0	0	0	0	0	27	1	13	4	6	0	41	0	2	3	0	0	0	0	0	0	0	0	0	0
78	DW9-52	NE	NE	30	41N	70W	4667	0.07	8.89	0	0	0	0	0	33	4	11	3	7	0	29	0	0	6	0	0	0	0	2	10	0	0	0	0
79	DW2-15	NE	NE	14	41N	71W	4740	-----	-----	0	0	0	0	0	23	4	24	19	5	0	17	0	0	5	1	0	0	0	0	1	0	2	0	0
80	DW2-229	SE	SE	22	41N	71W	4680	-----	-----	0	0	0	0	0	68	1	21	3	3	0	1	0	0	2	0	0	0	0	0	1	0	0	0	0
81	DW5-62	SW	SW	24	41N	71W	4760	-----	-----	0	0	0	0	0	60	6	1	13	2	0	3	0	1	1	0	0	0	0	2	10	0	1	0	0
82	DW2-5	NW	SE	1	42N	70W	4720	-----	-----	0	0	0	0	0	7	1	54	0	4	0	17	0	0	6	0	0	0	0	0	9	0	2	0	0
83	DW2-8	NE	SE	23	42N	70W	4860	-----	-----	0	0	0	0	0	3	2	60	0	6	0	23	0	0	5	0	0	0	0	0	1	0	1	0	0
84	DW2-6	NW	SW	7	43N	69W	4890	-----	-----	0	0	0	0	0	8	0	14	0	5	0	62	0	0	9	0	0	0	0	0	0	0	1	1	0
85	DW2-215	SW	NE	19	43N	69W	4710	-----	-----	0	0	0	0	0	12	1	33	8	10	0	33	0	0	0	0	0	0	0	0	0	0	2	0	1
86	DW2-3	NW	NW	22	43N	70W	4725	-----	-----	0	0	0	0	0	22	0	14	12	5	0	42	0	0	2	0	0	0	0	0	1	0	2	0	0
87	DW2-10	NE	SE	29	43N	70W	4690	-----	-----	0	0	0	0	0	7	1	26	14	6	1	35	0	0	5	0	0	0	0	0	1	0	4	0	0
88	DW0-35	NE	SE	34	43N	70W	4770	0.80	6.00	0	0	0	0	0	2	2	44	0	6	0	40	0	0	6	0	0	0	0	0	0	0	0	0	0
89	DW2-211	NW	NW	2	44N	70W	4830	-----	-----	0	0	0	0	0	16	1	10	1	5	0	61	0	1	2	0	0	0	0	0	1	0	2	0	0
90	DW2-212	NW	NW	2	44N	70W	4853	-----	-----	0	0	0	0	0	2	0	76	1	3	0	13	0	1	4	0	0	0	0	0	0	0	0	0	0
91	DW0-43	NE	NE	15	44N	70W	4700	0.20	15.28	0	0	0	0	0	10	0	78	1	4	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
92	HM4-4	SW	NE	18	45N	69W	4990	-----	-----	0	0	0	0	0	58	0	0	10	2	0	20	0	0	1	0	0	0	0	0	1	0	8	0	0
93	DW2-207	SE	SW	2	45N	70W	4820	-----	-----	0	0	0	0	0	11	4	14	2	1	0	64	0	0	2	0	0	0	0	0	2	0	0	0	0
94	DW2-207A	SE	SW	2	45N	70W	4820	-----	-----	0	0	0	0	0	19	0	21	5	8	0	38	0	0	5	0	0	0	0	0	1	0	1	0	0
95	DW2-213	SW	NE	23	45N	70W	4805	-----	-----	0	0	0	0	0	4	0	37	0	11	0	44	0	0	1	0	0	0	0	0	0	0	1	0	0
96	HM4-7	NW	NW	18	46N	69W	4920	-----	-----	0	0	0	4	12	0	4	4	0	0	0	68	0	0	4	0	0	0	0	0	0	0	4	0	0
97	HM4-5	SW	SE	32	46N	69W	5080	-----	-----	0	0	0	0	0	44	0	0	12	1	0	27	0	0	1	0	0	0	0	4	0	0	0	0	0
98	DW2-209	SE	SE	12	46N	70W	5000	-----	-----	0	0	0	0	0	25	0	37	10	4	0	21	0	0	3	0	0	0	0	0	0	0	0	0	0
99	HM4-6	SE	SE	12	46N	70W	4960	-----	-----	0	0	0	0	0	7	22	24	1	4	0	42	0	0	0	0	0	0	0	0	0	0	0	0	0
100	DW2-208	NW	NE	19	46N	70W	4655	-----	-----	0	0	0	0	0	23	1	19	7	10	0	32	0	1	6	0	0	0	0	0	0	0	1	0	0
101	DW0-40	NE	SW	30	46N	70W	4610	0.04	3.44	0	0	0	0	0	24	2	66	2	2	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
102	DW2-185	NE	NW	1	46N	71W	4540	-----	-----	0	0	0	0	1	26	0	32	10	3	0	23	0	1	2	0	0	0	0	0	0	0	2	0	0
103	DW5-71	SW	NW	12	46N	71W	4430	-----	-----	0	0	0	0	0	16	4	8	6	2	0	62	0	0	2	0	0	0	0	0	0	0	0	0	0

Table 2.—*Average percentages, standard deviations, and significance of difference between the means of nonopaque heavy minerals from the Wasatch and Fort Union Formations in the Reno Junction 30′ × 60′ quadrangle*

[Mineral identifications by W. A. Chisholm]

Age	Lithologic Unit	Number of samples analyzed[1]	Percent of heavy minerals in very fine grained sand fraction	Percent of magnetic opaque minerals in total heavy minerals	Heavy Minerals																								
					Pyroxene		Hornblende																						
					Augite	Hypersthene	Gray	Green-brown	Blue-green	Garnet	Epidote	Zircon	Sphene	Rutile	Zoisite	Tourmaline	Sillimanite	Kyanite	Staurolite	Andalusite	Monazite	Allanite	Diopside	Apatite	Biotite	Anatase	Chloritoid	Chlorite	Spinel
Abundance in percent (total nonopaque minerals = 100 percent)																													
EOCENE	Wasatch Formation Upper part	29 (7)	0.95	4.92	0.00	0.00	0.00	1.52	13.21	35.76	32.00	3.34	4.86	0.72	0.17	3.31	0.00	0.21	0.90	0.03	0.00	0.00	0.00	1.76	1.90	0.00	0.28	0.00	0.03
	Lower part	42 (7)	0.89	1.80	0.33	0.19	0.14	0.26	0.21	51.95	12.07	7.19	13.55	1.69	0.10	5.79	0.00	0.26	0.81	0.00	0.00	0.00	0.00	1.50	3.33	0.00	0.64	0.05	0.02
	Total Wasatch	71	0.91	3.08	0.20	0.11	0.08	0.77	5.52	45.33	20.21	5.62	10.08	1.30	0.13	4.77	0.00	0.24	0.85	0.01	0.00	0.00	0.00	1.61	2.75	0.00	0.49	0.03	0.03
PALEOCENE	Fort Union Formation Lebo Member	32 (7)	0.23	7.74	0.00	0.00	0.00	0.13	0.50	20.81	2.09	26.88	5.88	4.50	0.03	31.66	0.00	0.47	3.38	0.03	0.00	0.00	0.00	0.19	1.78	0.00	1.59	0.03	0.03
Standard deviation																													
EOCENE	Wasatch Formation Upper part	29	0.65	6.84	0.00	0.00	0.00	2.57	20.62	22.30	19.36	5.16	4.05	1.58	0.54	7.34	0.00	0.49	1.86	0.19	0.00	0.00	0.00	1.90	2.86	0.00	0.75	0.00	0.18
	Lower part	42	1.47	1.49	2.16	1.05	0.78	1.25	0.90	17.88	16.13	7.83	10.00	2.58	0.37	4.27	0.00	0.66	1.33	0.00	0.00	0.00	0.00	2.31	1.70	0.00	1.12	0.31	0.15
	Total Wasatch	71	1.12	4.40	1.66	0.84	0.60	2.53	14.56	21.23	19.99	7.09	9.14	2.26	0.44	5.81	0.00	0.60	1.56	0.12	0.00	0.00	0.00	2.14	4.09	0.00	[illegible]	0.24	0.11
PALEOCENE	Fort Union Formation Lebo Member	32	3.21	7.61	0.00	0.00	0.00	0.71	2.17	18.26	4.01	22.21	6.31	2.98	0.18	19.63	0.00	0.80	2.70	0.18	0.00	0.00	0.00	0.59	3.04	0.00	1.66	0.18	0.18
Significance of difference between the means																													
	Total Wasatch versus Lebo Member	Significance level 90 95 99			(2)	(2)	(2)										(3)			(2)	(3)	(3)	(3)			(3)		(2)	(2)

[1] Number of samples for which percentages of heavy minerals and magnetic opaque minerals were recorded are shown in parentheses

[2] Significance level of test of significance of difference between the means is less than 90% (.90) using two-tailed t test (Natrella, 1966)

[3] Test for significance of difference between means was not performed because all data values are zero

Table 3.—*Coal strip mines in the Reno Junction 30′ × 60′ quadrangle, Campbell and Weston Counties, Wyoming*

Map no.	Name of mine	Location	
1	Coal Creek	NW 1/4 sec. 17, T. 46 N., R. 70 W.	Campbell Co., Wyoming
2	Jacobs Ranch	SW 1/4 sec. 10, T. 43 N., R. 70 W.	Do.
3	Black Thunder	C. S 1/2, sec. 28, T. 43 N., R. 70 W.	Do.
4	North Antelope	NW 1/4, sec. 16, T. 41 N., R. 70 W.	Do.

CONVERSION FACTORS FOR METRIC EQUIVALENTS

To convert ENGLISH UNIT	Multiply by	To obtain METRIC UNIT
Mile	1.609	Kilometer
Foot	.3048	Meter
Inch	2.54	Centimeter

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